

CEMENT AND CEMENT MANUFACTURE

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Dry and Wet Process: Fuel Consumption and Kiln Efficiency.

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In this article it is the intention to examine in a general way the respective fuel consumption and kiln efficiency of the dry and wet methods of Portland cement manufacture. For this purpose it will be assumed that identical limestone and clay are used in two works, one operating on the dry process and the other on the wet. It is useless to make a comparison with such materials as chalk or marl, because their naturally wet state necessitates the use of the wet process, and, in the present stage of development of the industry, it would be absurd to attempt any other method. Limestone and clay, however, occur in many parts of the world, and are likely to raise the question as to which process has the advantage.

The limestone is assumed to contain 1.5 per cent. of moisture and the clay 10 per cent. The stone is assumed to contain at least 95 per cent. calcium carbonate. Each works has a kiln which normally produces 10 tons of clinker per hour. In the wet works, slurry containing, say, 40 per cent. of water, is fed to the kiln. The kiln and cooler combined have an overall length of about 300 ft., and the diameter of the kiln is, say, 8 ft. 6 in. with a firing zone enlarged to 10 ft. 6 in. The upper end of the kiln is furnished with chains hanging inside the kiln for a distance of some 60 ft. to 70 ft., for the purpose of more efficiently drying out the slurry. The gases escaping from the kiln have a temperature of from 375 deg. F. to 475 deg. F. At the lower end of the kiln a special clinker cooler is attached to the kiln, and clinker leaves the cooler at from 200 deg. F. to 300 deg. F.

Assuming that all the other conditions are reasonable, and as the purpose of this article is only comparative, it is unnecessary to enumerate them, and they

will be more or less common to both cases. The consumption of standard coal (having 12,600 B.Th.u.'s per lb.) will be in the neighbourhood of 24 per cent. per ton of clinker produced. But such a low flue-gas temperature precludes the utilisation of any of the heat contained in the gases in a waste-heat boiler, and, therefore, power to run the works must be generated separately.

It is difficult to dogmatise regarding the quantity of fuel which will be consumed for power purposes, as so much depends upon the efficiency of the works in question, particularly of the grinding plant, the fineness of grinding, the steam consumption of the prime mover, and the like. A very safe figure would be 14 per cent. of fuel per ton of cement produced, but it is probable that 12 per cent. would suffice, and for the present purpose at any rate the latter figure will be assumed. Thus the total fuel consumption throughout the wet process works, including burning and power, will amount to something in the neighbourhood of 36 per cent. of standard coal per ton of cement.

In the dry process works, the kiln to produce 10 tons of clinker per hour will be about 235 ft. long, including the cooler in prolongation, and, say, 8 ft. 10 in. diameter and 10 ft. 6 in. in the firing zone. The raw meal entering the kiln will be damped to the extent of about $7\frac{1}{2}$ per cent. of water, and the escaping gases will have a temperature of between 1,400 deg. F. and 1,500 deg. F. At the lower end of the kiln is a special clinker cooler, and, as with the wet kiln, it is attached to it. The clinker leaves the cooler at between 200 deg. F. and 300 deg. F. As before, assuming the other conditions are reasonable, the consumption of standard coal will be from 20 per cent. to 21 per cent. per ton of clinker, or, for the sake of the comparison, say, 20.5 per cent. As the raw materials contain a certain percentage of water, they must be dried before being finely pulverised, and therefore a further, say, 1.25 per cent. of fuel per ton of cement must be added to obtain the overall fuel consumption. This figure now becomes 21.75 per cent. per ton of cement for all purposes.

But a waste-heat boiler is attached to the dry kiln, and it is found that with this coal consumption there is sufficient heat in the escaping gases to generate steam in the waste-heat boiler for all the power required to run the kiln and its ancillary units. Therefore, in the case of the dry-process plant, the total fuel consumption for drying the raw materials, burning, and all power purposes is 21.75 per cent. per ton of cement, which is 14.25 per cent. better than the wet-process plant. If we assume that coal costs £1 per ton, this represents a saving of 2s. 10 $\frac{1}{4}$ d. per ton of cement in the special case under consideration, and the dry plant will show an annual saving of about £12,000 in this respect, but neglecting the other considerations indicated in the last paragraph of this article.

The distribution of heat uses and losses in the two kilns in question will next be considered. The chief ways in which the heat is used are indicated, and the distribution is what might reasonably be expected in both cases, although given in round figures for comparative purposes only. It must be emphasised that the cases are purely hypothetical and do not represent actual kilns which are in

operation. Although the figures are relatively accurate, they must not be taken as concrete examples of wet or dry process performance.

The following table, then, shows the approximate comparative distribution of heat uses and losses in two kilns, one wet and the other dry, using identical limestone and clay and producing the same output of 10 tons of clinker per hour. Slurry is fed to the wet kiln containing 40 per cent. of water, and $7\frac{1}{2}$ per cent. of water is contained in the raw meal fed to the dry kiln. The escaping gases from the wet kiln are at between 375 deg. F. and 475 deg. F., and from the dry kiln at between 1,400 deg. F. and 1,500 deg. F. Clinker comes from both kilns at a temperature of from 200 deg. F. to 300 deg. F. The consumption of standard coal in the wet kiln is 24 per cent., and in the dry kiln 20.5 per cent. per ton of clinker. Both kilns have a layer of insulating material between the fire-brick lining and the kiln shell, except in the firing zone:—

HEAT USES AND LOSSES.

Item.	WET KILN.		DRY KILN.	
	Coal per 100 lbs. clinker	Per cent. of total coal	Coal per 100 lbs. clinker	Per cent. of total coal
Reactions	6'00	25	6'00	29$\frac{1}{2}$
Water evaporation, superheating, etc.	10'44	43 $\frac{1}{2}$	1'02	5
Heat in flue gases from combustion gases and CO ₂	3'60	15	9'84	48
Heat lost in clinker leaving the system	0'36	1 $\frac{1}{2}$	0'36	1$\frac{1}{2}$
Radiation loss	3'00	12 $\frac{1}{2}$	2'77	13$\frac{1}{2}$
Unaccounted for	0'60	2 $\frac{1}{2}$	0'51	2$\frac{1}{2}$
Total	24'00	100	20'50	100

Examining these details, it will be noted at once that the distribution of heat between the main items is similar, except in the important respect that the heat required for water evaporation and superheating in the wet kiln is so much greater, while that available for use in a waste-heat boiler is so much less. It is unfortunate that the latent heat in the escaping steam from the wet kiln is unavailable for further use. In the dry kiln, the percentage of heat required for water evaporation is small, and the heat contained in the flue gases can be made to do useful work in a waste-heat boiler. Water evaporation on the dry plant amounts to about 5 per cent., while the heat available for the boiler is about 48 per cent., as against 43 $\frac{1}{2}$ per cent. and 15 per cent. respectively in

the wet kiln. It will be seen that the actual radiation loss from the wet kiln is a little greater than from the dry, although the percentage of total fuel used in this respect appears less. Actually the quantity of heat required for the chemical reactions must be the same in both cases, although the percentage of the total heat used is greater in the dry system, rendering the efficiency of the kiln, even considered as a separate unit, somewhat higher.

Considering the kiln as a complete unit in itself, the wet kiln is certainly as efficient as can be expected under present conditions in that it deals with a large quantity of water contained in the slurry, and the temperatures of both the escaping gases and of the clinker leaving the kiln are low. But we cannot fairly consider the dry kiln alone, and its efficiency must be computed after considering the waste-heat boiler and kiln as a single unit. About 65 per cent. of the escaping heat from the kiln can be used to produce steam in the boiler, allowing for about 5 per cent. radiation loss in the boiler system and 30 per cent. escaping from the boiler stack, provided proper precautions are taken to prevent the infiltration of cold air and so forth. Therefore, in addition to the $29\frac{1}{4}$ per cent. used for chemical reactions in the kiln, a further $31\frac{1}{4}$ per cent. must be added for the work done by the flue gases, making a total of about $60\frac{1}{2}$ per cent. for the overall efficiency of the kiln and boiler, against only 25 per cent. for the wet kiln.

Looking at the matter from a slightly different angle, it will be noted that in both kilns a certain temperature must be maintained in the firing zone to complete the calcination of the raw materials and to effect clinkering, and therefore a certain minimum number of British thermal units must in both cases be supplied from the coal burnt. When the work of calcination and clinkering is completed, the gases retain a similar and considerable quantity of heat. In the wet kiln this heat is utilised to dry out the slurry, while this function is practically unnecessary in the dry kiln, and the heat, which must be there in both cases, can be used in the dry method for power purposes.

This, then, is the position, and neglecting other conditions (as, for example, the fact that the raw materials will probably be more easily ground wet, the question of the efficient mixing of the raw meal on the dry process, interest on the additional capital necessary for the waste-heat boiler, the dust question, and the like), it is evident that in such cases as have been considered the dry method has a decided advantage, at least from the points of view of kiln efficiency and coal consumption.

Turkish Factory Augmentation.

The Soc. Anon. Ciments Arşlan company is increasing its capital by the issue of 38,500 ordinary shares, the proceeds of which are to be used for the erection of a new factory of considerable size near Constantinople.

Proposed New Australian Cement Works.

It is reported that a New South Wales company with Australian and English capital is to investigate a site for a proposed cement works near Brisbane.

An Up-to-Date United States' Plant.

EUROPEAN PRACTICE FOLLOWED.

WE have received from Messrs. Richard K. Meade & Co., consulting cement works engineers, of Baltimore, Maryland, U.S.A., the following description of the new plant of the Keystone Portland Cement Co., at Bath, Pa., in which many new features have been incorporated. We are indebted to Rock Products for permission to use this matter and the accompanying illustrations:—

The eyes of the cement industry have been on this plant ever since it started, when it was announced that it would be composed primarily of European-type machinery. At present only one unit of the plant is completed, consisting primarily of a crushing plant, two raw and two finish-grinding mills, two kilns, one coal-pulverizing unit and a battery of ten cement storage silos. Construction is well under way on the second unit. The guaranteed production per day is 3,000 bbl. (512 tons) a day, but one unit has produced as high as 3,300 bbl. per day, and it is expected that ultimately a production of 3,600 bbl. can be attained. In this case, the plant will eventually have a capacity of 7,200 bbl. per day.

The lay-out, operations, and processes are more or less on conventional lines. However, the design of the machinery is in many ways different from that commonly used. With a few exceptions, all the mechanical equipment was supplied by the Polysius Corporation.

The Quarry.

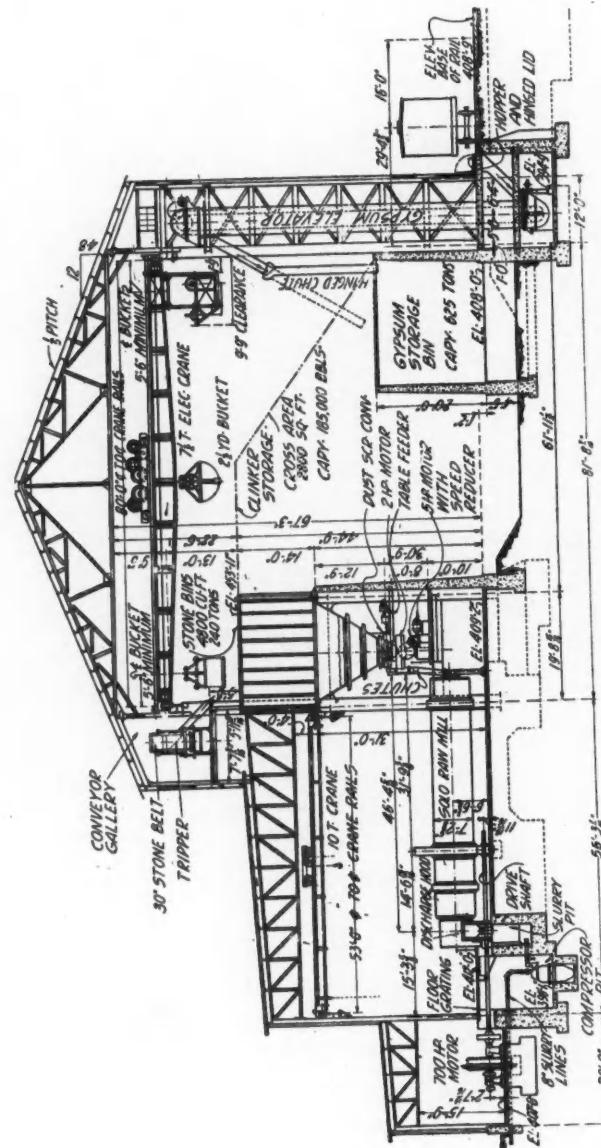
The face of the quarry is about 400 ft. long. Its height at one end is 40 ft., tapering down to 20 ft. at the other end. The stone has an overburden on an average of only 2 to 4 ft. of earth, which is removed by a $\frac{1}{2}$ -yd. petrol-driven shovel which loads into motor trucks. This earth is being used for a fill between the quarry and crushing plant at present, although there is sufficient dumping ground for several years' operation.

The deposit is composed of Lehigh Valley natural cement rock. The average of two analyses of samples of "high calcium rock" is SiO_2 , 6.75; R_2O_3 , 5.10; CaCO_3 , 85.52; MgCO_3 , 2.50. The average of two analyses of samples of "low calcium rock" is SiO_2 , 13.05; R_2O_3 , 7.76; CaCO_3 , 75.23; MgCO_3 , 3.75. The high calcium limestone is taken from one end of the quarry, and the low calcium limestone from the other.

Blast-hole drilling is done by two Cyclone and two Keystone machines, all of which are petrol driven. Two model 50-B Bucyrus-Erie electric shovels fitted with $1\frac{3}{4}$ -yd. dippers load into standard-gauge, 10-ton, all-steel cars, of which there are 12. Two 15-ton petrol locomotives do all the hauling, four and five cars to the train.

Crushing Plant.

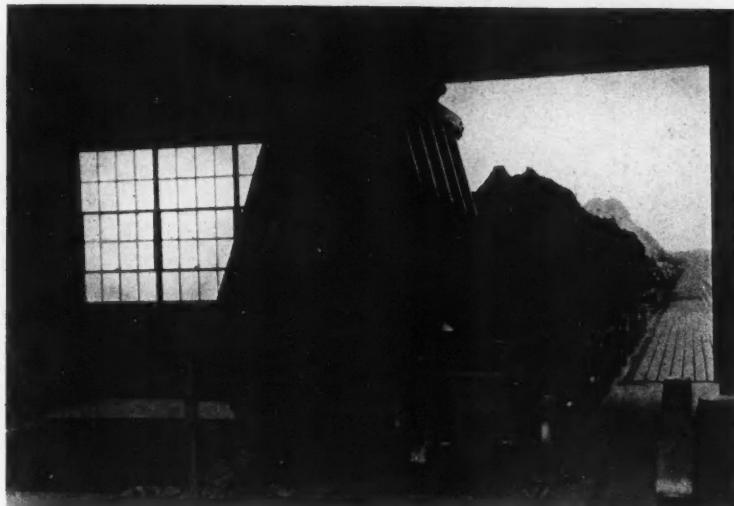
The grade between the quarry and crushing plant is very slight, and the distance is approximately 1,000 ft. The track extends through and beyond the



Sectional View through the New Grinding Mill House.

crusher building on a trestle 140 ft. long, which affords storage for loaded cars. Loads are pulled from the trestle to the dumping point by a 2-drum hoist operated by a 20-h.p. motor. (All motors, controllers and other electric equipment in the entire plant were furnished by the General Electric Co.) A cable on the other drum of the hoist is used for dumping the cars. Overhead is installed a 15-ton chain-operated crane for making repairs to the crusher, feeder, or motors.

The feeder forms the bottom of a hopper, 14 ft. square at the top, vertically lined with 80-lb. rails. It is 5 ft. 7 in. wide, 20 ft. long, and consists of five



Dumping to the Crusher. The Hoist which dumps the Cars also hauls them from the storage on the Trestle.

stationary bars and six moving bars, placed alternately, one with the other, and parallel to each other. The moving bars are connected at each end by a common shaft, and these two shafts are connected to and operated by an eccentric shaft. When operating, the moving bars rise, move forward a few inches, deposit their load of stone, move backward, rise, move forward again, and so on. It provides a positive and regular feed, the speed of which can be regulated, as the motor is of variable speed. The motor's speed range is from 600 to 1,200 r.p.m. and that of the eccentric shaft from 14 to 28 r.p.m.

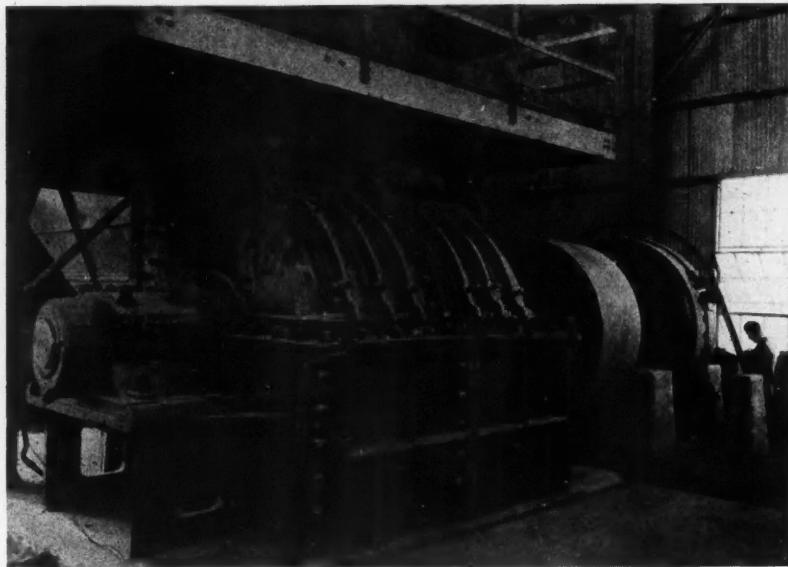
There is nothing unusual about the dimensions of the crusher, but it does remarkable work. It is capable of receiving a stone measuring 40 in. by 30 in. by 25 in. and reducing it to $\frac{3}{4}$ or 1 in. and smaller in one operation. It is known as the Solo crusher, is of the swing-hammer type, slow running, and has a guaranteed capacity of 250 tons per hour. This tonnage has been exceeded, however, by 100 tons. The crushing chamber is 79 in. in diameter and 87 in.

wide, and the main shaft and hammers, of which there are 48, each weighing 130 lb., are forged in one piece. The shaft is direct connected to a 350-h.p. Type TSR supersynchronous motor, through an American Crusher and Machinery Corporation magnetic clutch, and operates at a speed of 180 r.p.m. Power consumed by the crusher so far has averaged approximately 300 h.p. The fly-wheel of the crusher is fitted with a special type safety cut-out.

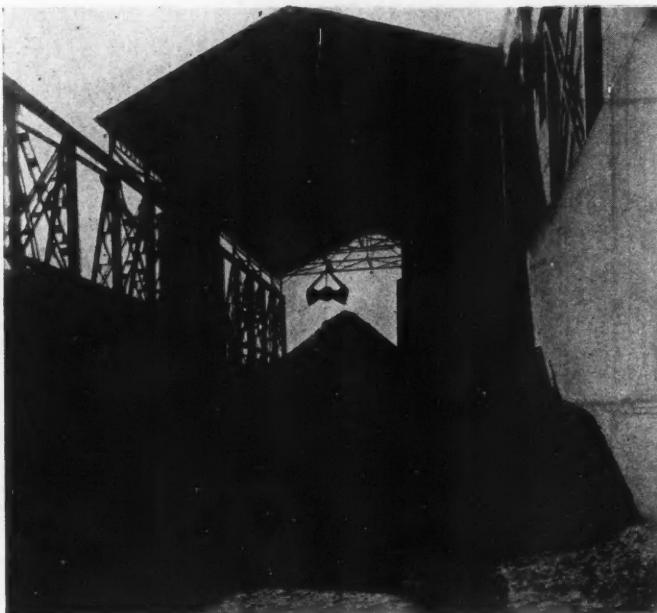
The output of the crusher is taken by gravity to a 36-in. conveyor belt of 355-ft. centres, housed in an inclined gallery extending from the crushing plant across the road and railway tracks to the raw materials storage. It can be made to discharge at any desired point in the storage yard, or into any of the raw material bins, through a portable shuttle-type tripper mounted on tracks over the conveyor. The conveyor is driven by a 40-h.p. motor through a 900:75 speed reducer.

Raw Materials and Clinker Storage.

The storage yard extends perpendicular to the centre lines of the mill building and kiln and coal buildings. It is 80 ft. wide, 40 ft. high and 500 ft. long and is served by a 6½-ton crane with a 2½-yd. clamshell bucket. The yard provides storage for 22,500 tons each of high and low calcium stone, 250,000 bbl. of clinker, 1,500 tons of gypsum, and 10,000 tons of coal. In addition, each of the stone bins over the raw-grinding mills has a capacity of 400 tons, the gypsum bins 100 tons each, and the clinker bins 1,800 bbl. each.



Swing Hammer Crusher.

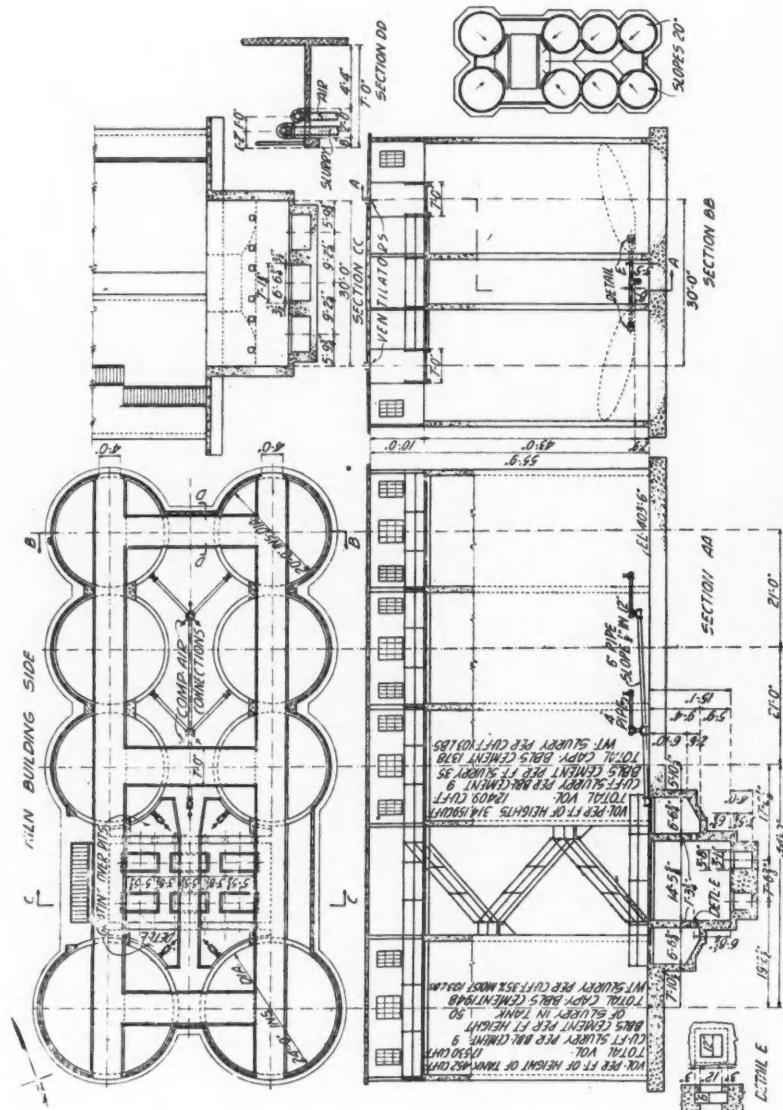


General Storage Yard.

Raw Grinding, Slurry Handling and Storage.

There are two 7-ft. by 42-ft. 8-in. raw-grinding mills, which are of the 3-compartment type, each driven by a 700-h.p. Type TSR supersynchronous motor running at 144 r.p.m. All joints in the mills are spliced and hammer-welded, and the only rivets used are those which fasten the partitions, manholes, and heads. Each mill is fed by a table feeder, 72 in. in diameter, which provides a positive and steady feed, said to be within a tolerance of 1 per cent. of accuracy. These feeders are each driven by a 5-h.p. Type CD direct-current motor through gearing.

From the mills the slurry is chuted to a pit and from the pit by gravity to two sets of "Pressors," which pump it directly to the storage tanks. These machines are one of the most unique pieces of machinery in the plant. They are entirely self-contained, automatic, and operated by compressed air. A set consists of two "Pressors" interconnected in such a way that while one is filling with slurry by gravity the other discharges by pressure. Both the inlet and outlet lines enter each receiver at the bottom. The interior contains a float, which, when the machine is full, connects with a control mechanism that reverses the action and admits the air pressure at the top, thus forcing the slurry into and through the line to the desired tank or pit. It is claimed that one of the greatest advantages of this type of machine is that because the com-



Plan and Elevation of Slurry Tanks.

pressed air follows the slurry column it keeps the line clean at all times. In any event there is a continuous and automatic movement of the slurry at a speed of 90 bbl. per hour per set of "Pressors." Each machine is equipped with a recorder so that there is an accurate knowledge of the number of charges or discharges per hour or day.

Six concrete silo-type tanks, 45 ft. high and 20 ft. in diameter, each having a capacity of 1,378 bbl., receive the slurry as it comes from the mills. Here is another new kind of apparatus in the form of the "Regulex" system of agitation. There are no mechanical agitators, and the operation is entirely dependent upon compressed air. This is introduced into each tank through 28

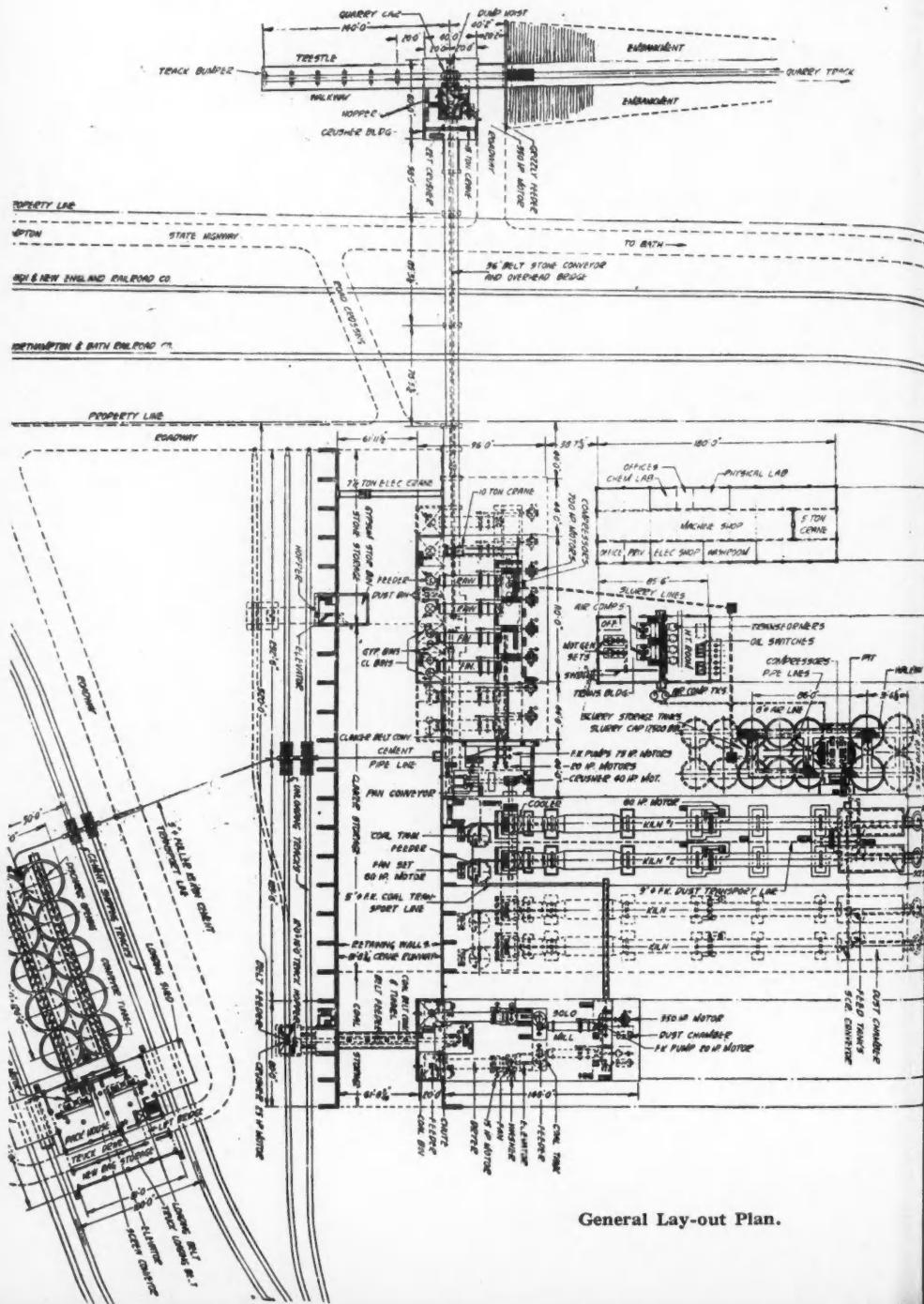


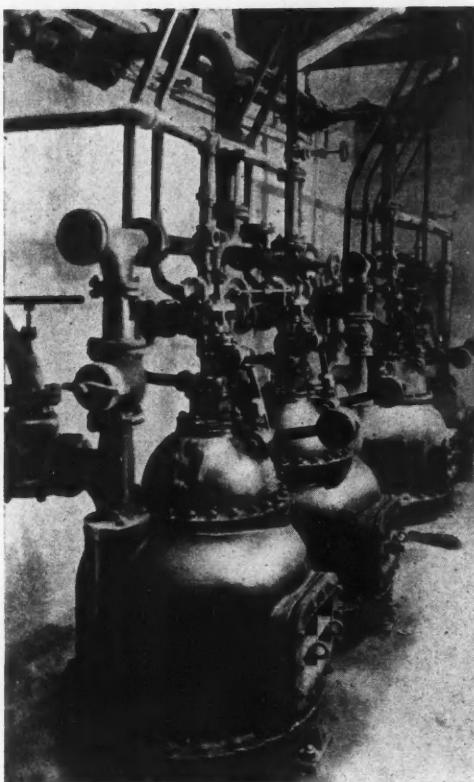
Two Raw Grinding and Two Finish Grinding Mills and Motors.

separate $\frac{3}{4}$ -in. lines, extending to within a few inches of the bottom of the tank, which lead off of two $2\frac{1}{2}$ -in. main lines mounted over the tops of the tanks.

The "Regulex" system was installed to provide for uniformity and regularity of agitation in each tank. It is simply an automatic control apparatus which may be set to allow any desired period of agitation for each tank, and to shift from one tank to the other in any desired order or completely to omit one or more tanks. The normal operation, however, would call for it to provide agitation in the six tanks one after another in rotation.

The six tanks drain into one common pit from which the slurry is pumped by two sets of "Pressors" to either one of two concrete blending tanks, 24 ft. in diameter by 45 ft. high. After correction the slurry flows into another pit and from this pit two sets of "Pressors" pump it directly to the kiln-feed tanks. Both the slurry pits are fitted with automatic floats which prevent the possibility

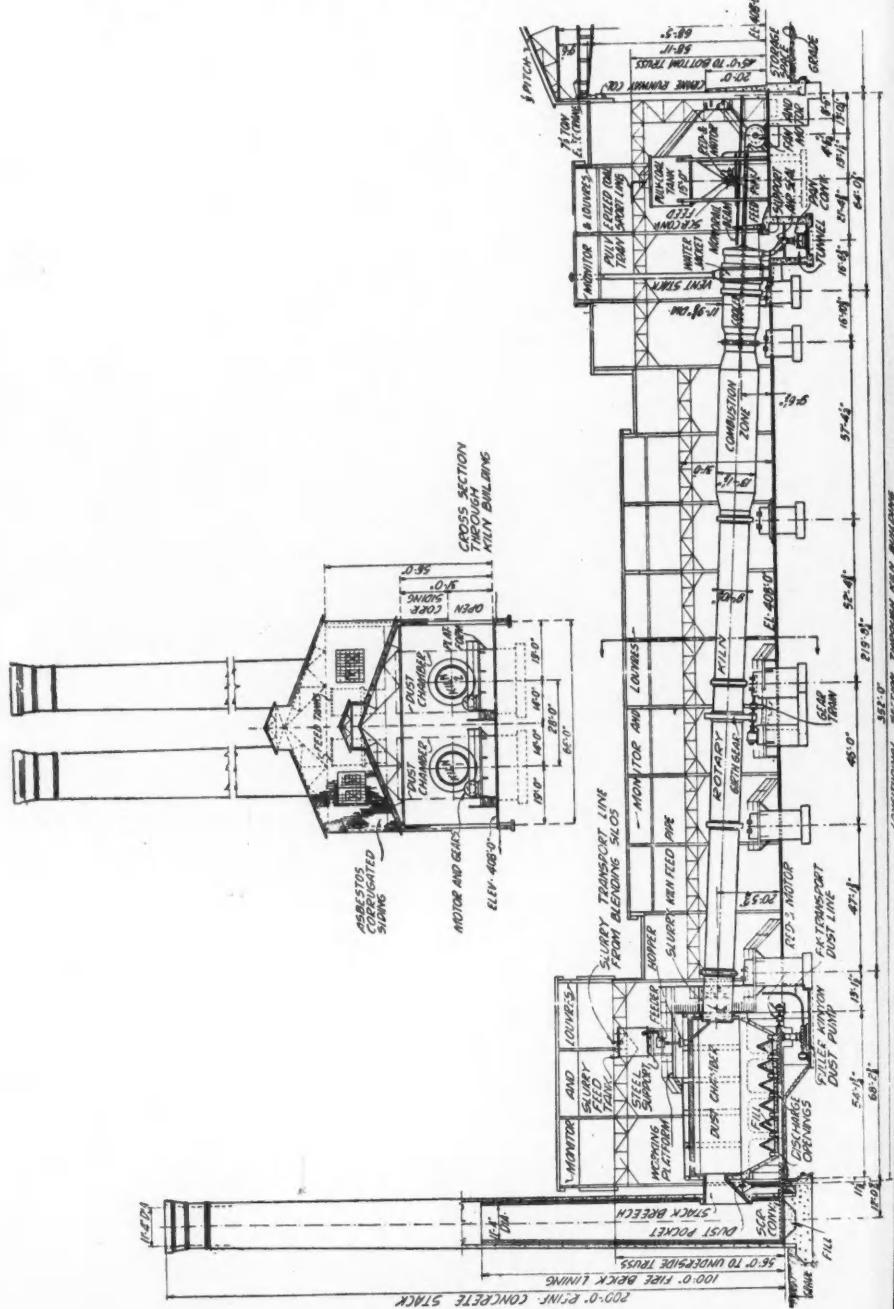




Two Sets of "Pressors."

of flooding. The kiln-feed tanks are 9 ft. in diameter and 10 ft. high and are mounted directly over the kilns. Feed to the kiln is by gravity, and regulated by a revolving disk with eight different sized openings. To reduce the feed it is only necessary to feed through a smaller opening, or vice versa, as desired.

The construction of the slurry tanks is somewhat novel, and is the design of Messrs. Richard K. Meade & Co., consulting engineers, of the Cement Company. In building these tanks sliding forms were used. The tanks themselves are 45 ft. high. When this height was reached the inside of the forms was blocked off, the outside walls of the tanks built up another 10 ft., and a concrete roof slab thrown over the whole, thus forming a gallery above the tanks and an economical all-weather concrete structure. This roof rests on the side walls and on steel beams, which in turn are supported by two rows of columns at the tank intersections.



Kilns.

The total length of each kiln is 250 ft. At the feed end there is a 10-ft. diameter section 165 ft. 10 in. long, then a funnel-shaped section 6 ft. 2 in. long, followed by a 38-ft. section 13 ft. 3 in. in diameter; then another funnel or taper of 6 ft. 2 in. length, a 6 ft. 2 in. section 10 ft. in diameter, a 2-ft. funnel connection, and finally a 25-ft. 8-in. section, 12-ft. in diameter. The kilns, too, are known by the name "Solo," for in addition to drying, calcining, and burning they also accomplish in a single operation the cooling of the clinker. This is done in the 12-ft. diameter section at the firing end. Each kiln is mounted on six self-aligning, water-cooled bearings and is driven by a 60-h.p. direct-current motor through a special arrangement of gearing.



The Kilns.

There are two pulverized-coal bins over the kilns, each having a capacity of 43½ tons, with bottom spout discharge. Two small screw conveyors feed the coal from each bin into the main feed-pipe for each kiln. The feed line to each kiln is adjustable forward or backwards to or from the kiln, and may be turned as desired. The line in each kiln extends 30 ft. through the cooling chamber to the firing zone, with no supports. Each line is made up of 10-in. pipe mounted within a 14-in. pipe, so that, by passing air between the two pipes as the coal is being blown through the inner one, the coal is kept cool as it passes through the cooling zone and until it reaches the firing zone. The coal feed blowers are of a special type and are driven by 60-h.p. motors through flexible couplings. Up to the present the guaranteed maximum coal consumption of 95 lb. per barrel of clinker has not been exceeded.

Each kiln is fitted with a large concrete dust-settling chamber, having a V-shaped bottom, in which operates a screw conveyor. The conveyor empties directly into a 4-in. Fuller-Kinyon pump, which conveys the dust several hundred feet to two bins over the raw grinding mills. (It is introduced into each mill from the bins by means of a double-screw conveyor, driven by a 2-h.p. direct-current motor through a special reducer.) The dust chambers are located directly between the kilns and the stacks. The latter are of concrete, 218 ft. high, 18 ft. in diameter at the bottom and 12 ft. in diameter at the top.

Coal Plant.

Coal is unloaded from hopper-bottom railway trucks into a track hopper. (The track for incoming coal and gypsum is parallel to the storage.) As it is unloaded, the coal drops direct into a large tapered-bottom steel bin, from which it is fed by a special type mechanical feeder driven by a $7\frac{1}{2}$ -h.p. motor through a 906:90 speed reducer. This feeder serves a small Link-Belt coal crusher driven by a 25-h.p. motor through a 3:8:1 Link-Belt-Sykes speed reducer. The crusher discharges on a 20-in. belt conveyor extending through a tunnel under the storage leading direct to the coal plant. Here it is elevated in an enclosed chain-bucket elevator and emptied either into a steel tank over the coal dryer or discharged into storage. For reclaiming from storage there are openings in the tunnel through which the coal falls to a portable table-feeder mounted over the main conveyor. Thus the conveyor is used not only for conveying from the crusher, but also from the storage to the plant. It is driven by a 15-h.p. motor through a 900:30 speed reducer.

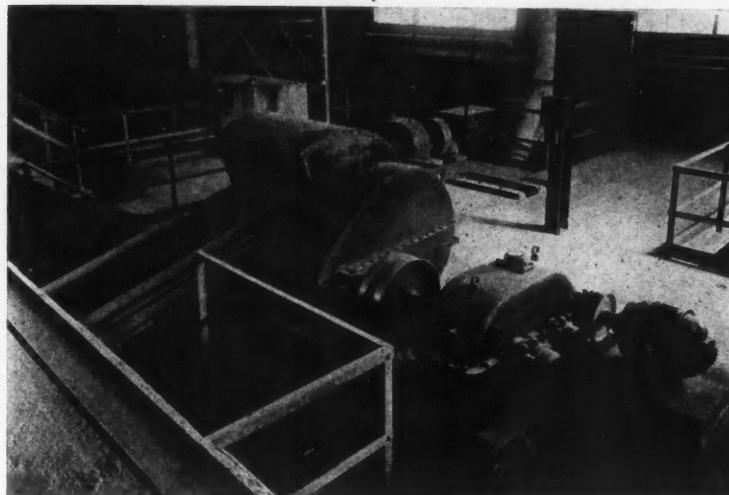
The dryer is 6 ft. in diameter, 60 ft. long, mounted on two tires, and driven by a 15-h.p. motor through gearing. Its firing chamber is equipped with an automatic stoker driven by a 3-h.p. direct-current motor.

An interesting feature here is an exhaust gas washer, or scrubber, with which the dryer is equipped, to prevent the discharge of dust from the chimney of the drying plant. It consists of two vertical cylindrical chambers, interconnected one above the other, with a suction fan driven by a 15-h.p. motor between them. The waste gases and fine dust drawn from the dryer enter the bottom of the lower chamber through a pipe provided with a conical cap which deflects the gases and dust towards the walls of the chamber. A series of nozzles is located above the cap of the smoke-inlet pipe, and the water spraying from the nozzles produces a heavy penetrating mist which completely fills the chamber. The gases have to pass through this dense mist, which scrubs them and precipitates the coal dust to the bottom of the chamber from which it flows through a pipe to a settling basin. The scrubbed gas, leaving through the top of the lower chamber, enters the fan which in turn discharges it to the upper washing chamber in the same manner as it entered the lower one. Here the gas is again scrubbed by another series of water sprays, and any dust not caught in the first washing is precipitated to the bottom of the chamber and carried to the settling basin. The waste gas, now free of dust, is discharged into the atmosphere through a stack mounted on top of the upper chamber.

The dryer discharges into the boot of an enclosed, chain-bucket elevator,

which empties into a steel bin over the grinding mill. The bin feeds directly to a table feeder and under the feeder is a special type weighing device which furnishes a graphic record of the number of pounds of coal per minute fed to the mill and thence to the kiln.

The mill is 6 ft. in diameter, 39 ft. long, and is driven by a 350-h.p. Type TSR supersynchronous motor direct connected through an elastic coupling. The mill is in three compartments, the first being charged with $2\frac{1}{2}$ -in. media, the second with $1\frac{1}{2}$ -in. and the third with punchings (about $\frac{7}{8}$ -in.). The rated capacity of the mill is six tons per hour and its product is 99 per cent. through a 100-mesh sieve. It discharges direct into a 6-in. Fuller-Kinyon coal pump



View of a typical Drive.

which conveys to the storage tanks over the kilns. (A second pump is being installed to be used as a stand-by.)

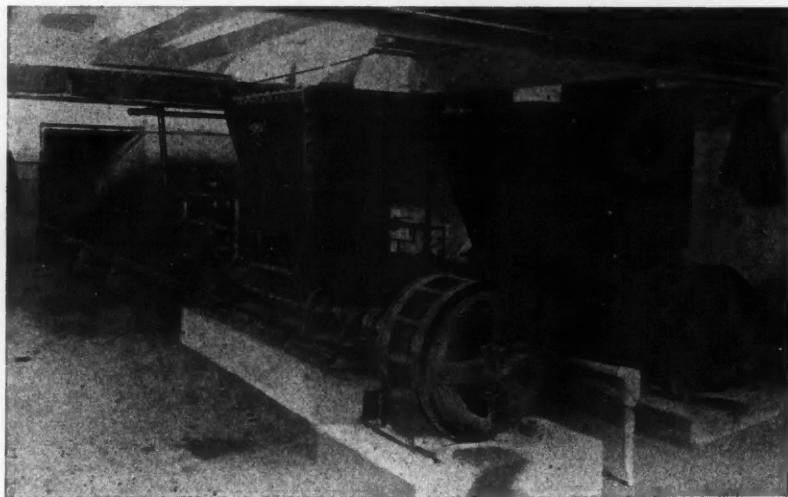
Dust from the mill is caught by a special type of collector mounted on a platform behind and over the discharge end. It is of the suction filter-tube type and is in five sections of 8 tubes each. It is enclosed in a steel cabinet with large doors, affording accessibility for repairs. A 20-h.p. motor drives its 56-in. fan.

Finish Grinding.

Clinker is chuted from the cooling zone of the kiln into a 36-in. pan conveyor running perpendicular to the centre lines of, and under, the kilns. It extends horizontally for 38 ft. and then rises at an inclination of 16 deg. for a distance of 26 ft., where it empties into a crusher. This machine is a heavy 2-roll breaker and is driven by a 40-h.p. motor through a 900:75 speed reducer. It discharges into another 36-in. pan conveyor of 32-ft. centres, inclined also to 16 deg.,

which empties into an enclosed chain-bucket elevator. The elevator can discharge either into the general storage or on a 36-in. belt conveyor, of 96-ft. centres, serving the mills. This conveyor is of exactly the same type as the stone conveyor and operates in the opposite end of the same gallery. It is driven by a 10-h.p. motor through a 900: 30 geared and enclosed speed reducer.

The 1,800-bbl. clinker bins are directly over the head-end of the mills, and they feed into 72-in. table feeders serving the two 7-ft. by 42-ft. 8-in. Solo mills, the installation and motors of which are identical to those of the raw grinding mills. Gypsum is fed to each mill by a 40-in. table feeder; one $7\frac{1}{2}$ -h.p. motor drives one clinker and one gypsum feeder through a special gear-box and



Cement Pumps.

shafting. Each mill is equipped with an 8-section (64 tubes) dust collector operated with a 56-in. fan and 25-h.p. motor.

The finished cement is moved in a screw conveyor for a short distance to two 6-in. Fuller-Kinyon pumps (one is held in reserve as a spare), each driven by a 75-h.p. motor. From here the cement is pumped approximately 330 ft. underground to the silo storage tanks.

Packhouse and Silos.

The packing house is a 4-storey all-concrete building, 80 ft. wide and 81 ft. long, at the end of two rows of silos and having facilities for truck loading at one end and lorry loading at either side. There are ten silos, each 30 ft. in diameter and 90 ft. 6 in. high, which, with the interspaces, have a total capacity of approximately 153,000 bbl. These silos are of the Meade type. They are self-emptying; the screw conveyors are in covered passage ways which run

through the silos, and the weight of the cement is distributed over the whole supporting mat.

Cement is drawn from the silos into screw conveyors, of which there is one for each row of silos. Each conveyor discharges into its own cross-screw, which feeds into an enclosed chain-bucket elevator. Each set of conveyors is driven by a 40-h.p. motor through a 900:75 speed reducer. The elevators discharge into two screw conveyors on the third floor, which distribute to the desired packer bins. Cross-discharge spouts are provided in the elevators, so that it is possible to discharge from either elevator to either of the two conveyors. These conveyors are end to end in the same casing, but convey in different directions, each serving two packers on the floor below.

On the first floor there are two pairs of 3-tube Bates packers, each pair served by a belt conveyor. One pair is for loading on one track; the other for loading on the track on the opposite side of the building. Each packer is driven by a 20-h.p. motor and each conveyor by a 3-h.p. motor. Spillage from the packers is received in a screw conveyor which empties into the elevators. For checking weights there are two platform scales.

The balcony floor provides storage space for both paper and cloth bags. On the second floor are two 40-tube dust collectors for the four packers, and this floor is also used for the storage of bags. The third floor houses the bag cleaner and its dust collector, which also is of the 40-tube size. The bag cleaner is of special design built by the Bethlehem Foundry & Machine Co., but is of the usual rotary type and has a capacity of 30,000 bags per day. It is sprocket-chain driven by a 25-h.p. motor through a 9 $\frac{1}{2}$:1 speed reducer. A 36-in. belt conveyor removes the bags for sorting and repairing as discharged. The third floor also has storage space for corrugated truck-lining paper. The fourth floor provides headroom for the elevators and the bag cleaner as well as storage space for bags. The fans of the three dust-collectors in the packhouse are each driven by a 20-h.p. motor, and, like the collectors in the other parts of the plant, the screw conveyors which remove the dust from them are driven from an off-shaft of the fan motor through a 3-h.p. speed reducer.

The plant was designed and built under the supervision of Messrs. Richard K. Meade & Co., with the co-operation of Messrs. Fred B. Franks and W. J. Swegman, chief engineer of the Keystone Portland Cement Co., and the Polysius Corporation.

Proposed Australian Extensions.

The Swan Cement Co. is proposing to increase its capacity by 50 per cent., bringing it up to about 60,000 tons per annum, in order to supply cement for a concrete pipe plant to be erected in Western Australia—presumably near the cement plant at Riverdale, two miles from Perth.

Lubrication of Cement Works.

By F. J. SLEE, B.A., B.Sc.

THE correct lubrication of a cement works is a problem deserving the closest attention of those responsible for the maintenance of the plant and for its most economic operation. This fact becomes more apparent when consideration is given to the fact that there is always present in cement works a fine abrasive dust which must be kept away from the bearing surfaces as well as possible under working conditions.

It is therefore advisable, where oil is used on open bearings, to slightly over-lubricate rather than to under-lubricate, so that the effluent oil from the bearing ends tends to carry away the abrasive dust that might otherwise penetrate into the bearing surfaces. This naturally leads to a high consumption of lubricant, but economy can be effected by collecting the used oil wherever possible and using this, after filtration, for rough lubrication such as for quarry-car axles.

Again, wherever possible grease lubrication should be employed, as obviously grease will prevent the fine dust from entering bearings without resort to the over-lubrication generally employed when oil is used.

Care must be taken that all oil is kept as free as possible from atmospheric contamination. All cover plates should be kept closed and all oil containers covered.

Let us now consider the selection of lubricants for the various plant commonly found in cement mills.

Power House.—This plant requires the same lubrication as all power plants whether in cement works or not, and very little special attention is required.

Excavators.—These are usually steam driven, and as low-temperature saturated steam is invariably employed a comparatively cheap dark cylinder oil can be used. A closed flash point of about 480 deg. F. and a viscosity of 900 to 1,000 seconds Redwood No. 1 at 140 deg. F. is sufficient indication of a satisfactory oil which we will call, for the purpose of this article, "Cylinder Oil No. 1." A medium red bearing oil of about 120 to 140 seconds viscosity at 140 deg. F. will be suitable. This will be called "Bearing Oil No. 1." Recovered oil may be used on the wire ropes.

Locomotives.—Cylinder Oil No. 1 and Bearing Oil No. 1 will be suitable for these, the latter being recommended also for the locomotive axles.

Steam Wagons.—Where saturated steam is used Cylinder Oil No. 1 will be satisfactory. Wagons of comparatively recent design employ superheated steam, and a high-class cylinder oil having a minimum closed flash point of 535 deg. F. and a viscosity similar to that of Cylinder Oil No. 1 should be specified, here called "Cylinder Oil No. 2."

The bearings of over-type wagons can be efficiently lubricated by Bearing Oil No. 1, whilst for undertype wagons a crankcase oil must be employed ("Crank-

case Oil No. 1"). This should have a good demulsification from water and a viscosity of 150 to 200 seconds at 140 deg. F.

Trucks and Tubs.—Recovered oil is quite satisfactory for these.

Conveyors.—If these are lubricated by grease cups a medium lime base cup grease is most suitable having a melting point of about 200 deg. F. ("Cup Grease No. 1"). Cylinder Oil No. 1 should be used on the chains; where ring-oiled bearings are employed use Bearing Oil No. 1.

Crushers.—On the bearings of jaw-type crushers a heavy bearing oil having a viscosity of about 200 seconds Redwood No. 1 at 140 deg. F. (" Bearing Oil No. 2") should be used, whilst a thick black grease must be employed for the lubrication of the open gear. For the bearings of the rotary-type crushers Bearing Oil No. 1 or Cup Grease No. 1 should be put forward, and Bearing Oil No. 1 would also be used for the enclosed gears.

Rolls.—The main bearings here may be lubricated with either Bearing Oil No. 2, Cylinder Oil No. 1, or a mixture of these. The selection should be left to the discretion of the plant engineer.

Slurry Pumps.—Where it is desired to lubricate the plunger of these pumps, an engine oil compounded with fatty oil and of the same viscosity as Bearing Oil No. 1 should be used (" Bearing Oil No. 3"). A pure mineral oil would be washed away by the slurry.

Open gears should be lubricated with a thick black grease, whilst the main bearings should be lubricated with Bearing Oil No. 1.

Kilns.—Heavy slow-speed trunnion bearings are generally lubricated with a high-melting-point sponge grease. In some cases yarn is impregnated with this grease in order to prevent the grease slowly seeping from the box. A good class of sponge grease should have a minimum melting point of 300 deg. F. and a mineral oil content of 75 per cent. The rollers which support the kiln should be lubricated with Cylinder Oil No. 1. The open gears would have black grease applied to the pinion teeth, and high-speed enclosed reduction boxes would run satisfactorily with Bearing Oil No. 1.

Coolers.—The trunnion bearings here are lubricated in a similar manner to the kilns, as also the rollers and open and enclosed gears.

Cooler Fans.—Motor and fan bearings should have Cup Grease No. 1 or Bearing Oil No. 1.

Grinders.—The lubrication here is similar to the crushers.

Electric Motors.—These should use Bearing Oil No. 1.

Wash Mills.—The main bearings of these mills should be lubricated with Cylinder Oil No. 1; likewise the worm gears. Open gears would take black grease, and any high-speed exposed bearings should be lubricated with Bearing Oil No. 3.

Screens.—For enclosed gears and bearings Bearing Oil No. 1 is recommended. For slides, cams, rollers, cheap Cylinder Oil No. 1 should be used, and heavy black grease on open gears.

Tests for Lubricants.

In the foregoing, various terms have been employed such as viscosity, flash point, etc., and a brief description of these tests may be useful.

Flash Point.—The flash point of an oil is the temperature at which in a certain apparatus the vapours given off by the oil ignite when brought into contact with a flame. In this country the Pensky Marten apparatus is chiefly used. A fixed quantity of oil is heated in a metal cup of standard dimensions closed from the air until the vapours ignite momentarily when brought into contact with a small flame. The temperature at which this occurs is called the "closed flash point." The cover of the cup is then removed, and at about 20 deg. F. above the closed flash point the oil vapours open to the air ignite momentarily when exposed to a flame. This is known as the "open flash point." At a still higher temperature the vapours ignite and continue to burn, and this temperature is known as the "fire test."

Viscosity.—The viscosity of an oil is the property commonly described as its "body" and gives a measure of its fluidity. Thus an oil of high viscosity is a thick sluggish oil, while one of low viscosity is a thin mobile oil. A thick oil obviously flows more slowly than a thin oil, and this is made use of in testing viscosity. The viscometer in common use in England is the Redwood viscometer. A fixed quantity of oil is placed in a cup of standard dimensions in the base of which is an agate hole, again of standard dimensions. The time in seconds required for 50 ccs. of oil to flow through this hole at any given temperature is the "Redwood Viscosity" at that temperature. Thus, if an oil has a Redwood Viscosity of 500 seconds at 70 deg. F. it means that the time required for 50 ccs. of this oil to flow through the hole in a standard Redwood Viscometer at 70 deg. F. would be 500 seconds.

The higher the temperature of an oil the thinner it becomes, i.e. the viscosity becomes lower; as a consequence the temperature at which the viscosity of an oil is taken is of great importance. Viscosity is a selective test, as by it the suitability of an oil for a specific purpose is largely governed. The correct lubricant for a specific purpose is the lowest viscosity lubricant which will maintain a lubricating film under the conditions of use. If a lubricant is selected which is too thin to maintain a film under the particular conditions, satisfactory lubrication will not be obtained. If, however, a lubricant is selected which is thicker than that required to produce a film, loss of power will result from too great fluid friction. Thus, to quote absurdities, steam cylinder oil is obviously too thick to lubricate a watch, and oil suitable for a watch is too thin to maintain a film in a steam cylinder. The temperature at which the viscosity is taken is of great significance; thus a bearing oil should have its viscosity taken at a temperature of 140 deg. F., whereas the viscosity of a refrigerator oil at high temperature is of little value.

Saponifiable Matter.—The percentage of saponifiable matter in an oil is the percentage of fatty oil added to the oil. The addition of fatty oil to a mineral oil is recommended in cases where the lubrication is "wet."

Notes from Abroad.

New French Works.

We understand Chaux et Ciments de Lafarge have procured a site at Angouleme (Charante), Bordeaux district, and are proposing the construction of a 100,000-ton cement plant.

German Cement Production.

Production during 1928 by members of the Zement Bund was about 7,570,000 tons against 7,340,000 tons for the previous year, and the total production and imports was about 8,400,000 tons. Deducting exports of just over a million tons, an approximate consumption of 7,300,000 tons is estimated for the past year.

New Czechoslovakian Aluminous Cement Plant.

During 1929 the works at Beraun of the Konigshofer Cement Fabrik are to be overhauled, and an aluminous cement plant is to be erected at this firm's Techischknowitz plant. An increase in the total capacity of the company from 750,000 tons to 950/1,000,000 tons is anticipated.

New Cement Works in Jugo-Slavia.

We understand a Belgo-American consortium is planning the establishment of a 400,000-ton per annum cement plant in the neighbourhood of Spalato. Aluminous cement will also be made.

Increased Production in Chile.

The El Melon Cement Co., with an output of 125,000 tons of cement per annum, is proposing to add a further kiln, bringing its capacity up to 170,000 tons per annum. The estimated consumption of the country for 1928 is 215,000 tons.

Improvements for Canadian Concern.

The Canada Cement Co. propose to expend several millions of dollars on developments during this year, and as a first step a depot is to be built in Quebec at a cost of \$1,000,000. A special wharf is also proposed on the St. Charles River.

Imports into Finland.

Cement imports into Finland during the period January to July, 1928, amounted to 31,079 tons against 14,908 tons during the corresponding period of 1927. The two factories "Pargas" and "Lojo" are to increase their capacity from 650,000 casks to 1,100,000 casks per annum.

Proposed Rhodesian Cement Increase.

The Premier Cement Co. (Rhodesia), Ltd., intend to make improvements to its works this year at a cost of £30,000, and a production of 60,000 bags per annum is to be aimed at. This company, which is capitalised at £100,000, is controlled by the Pretoria Company and operates in S. Rhodesia.

Aluminous Cement in Germany.

The Rolandshutte plant of Hochofenwerk Lubeck A.G. is stated to be successfully manufacturing an aluminous cement from china clay.

Brazil.

Official import figures for the first three months of 1928 are now available, and show cement importations as follows:—January-March, 1927, 105,665 metric tons; January-March, 1928, 115,357 metric tons.

Australia.

The following paragraph recently appeared in a Sydney, New South Wales, newspaper: "Now in Sydney in connection with a big mission is Mr. Emil Tonnesen. He is one of the best-known cement experts in the world, and has been closely associated with the erection of cement plants valued at 10 millions."

The Goliath Portland Cement Co. has been formed to take over the Tasmanian Cement Co.'s plant at Railton. The company is capitalised at £600,000, and the purchase price is £270,000.

Proposed Canadian Reconstruction.

The Canada Cement Co. has under consideration the reconstruction of their Hull (Ontario) plant at a cost of over half a million dollars.

New Cement Factory in Chile.

It is announced that a company is being formed for the installation of a cement factory to exploit the deposits of limestone at Batuco, said to be suitable for the purpose.

Indian Cement Industry.

The *Indian Concrete Journal* states:—"Since 1925 the demand for cement has grown steadily until to-day consumption is nearing the maximum production point. In some instances, there may even have been difficulties on the part of the potential consumer to obtain the supply to meet his demand. The enquiry, therefore, naturally arises as to what provisions are being made to meet this increasing demand, and we are able to inform our readers that adequate provision is being made. Within the next six months three more kilns will be erected by companies each widely separated, and this alone will mean an increased production capacity of about 25 per cent. of the present output in the country. Further to this, there is an existing works with two kilns being restarted after lying idle for a few years. Thus the cement user can rest assured that his demands will be met, and met with cement up to the high standard that the trade in India has now set for itself. The total consumption of cement in India during the year 1927 has risen to more than three times as much as in 1914, and cement manufactured in India has increased from being only an insignificant fraction of that consumption to nearly 88 per cent. of the total."

Calcium Chloride and Cement.

By Dr. C. R. PLATZMANN.

THE peculiar behaviour of cement in contact with calcium chloride has been for years the object of scientific and commercial inquiry; the former can be traced back as far as 1886 (Candlot, Le Chatelier, Heintz). In recent years this problem has been studied by Spiegelberg, the present director of the Degerhamm cement plant (Sweden), Dr. F. Killig, and the director of the Düsseldorf Cement Institute, Dr. A. Guttmann, and V. Frost, of the Swedish State Testing Laboratory.

Guttmann's investigations bore special reference to the beneficial effect of calcium chloride on shrinkage of cement. He demonstrated that curing specimens of Portland and iron Portland cement in a saturated Ca Cl_2 -solution (50 per cent.) resulted in their complete deterioration, while slag cement specimens showed only a reduction in strength. Spiegelberg used in his tests cements with considerable admixtures of gypsum, and showed the beneficial effect of calcium chloride in preventing unsoundness. In individual cases Schindler has found that unsoundness due to gypsum is produced in spite of calcium chloride admixtures, a fact confirmed by Guttmann. However, when gypsum is added in amounts greater than 9 per cent., unsoundness results in spite of Ca Cl_2 admixtures up to 2 per cent. Further, Spiegelberg obtained, with the use of calcium chloride admixtures, values of compressive strength up to 200 per cent. above standard, while the tensile strength showed little or no increase.

These deviations from the standard strength values are obviously the most remarkable feature of the effect of calcium chloride on cement. It is notable in this connection that the increase in compressive strength is more pronounced in rotary-kiln products, while those of the shaft-kiln show a less marked effect. Basing his conclusions on original tests, Killig offers the following explanation of the observed increase in strength: As lime is more soluble in Ca Cl_2 solutions than in water, the reactions taking place during setting are accelerating through increased formation of crystals as well as higher temperature during setting. Killig also demonstrated that admixtures of calcium chloride produce greater constancy of volume in cement.

Such was the general position as recorded in available literature when I was confronted with the problem—before the introduction of early-high-strength cements in Germany—of producing a concrete of high early strength and also showing the least amount of shrinkage. It seemed adequate in seeking to satisfy these requirements to make an investigation of Ca Cl_2 admixtures, and this investigation is here described.

The cement first used in these tests conformed to the German Standard Specifications (1909) with regard to fineness, soundness, chemical analysis and time of setting. Compression and tensile tests were made of 1:2 and 1:3 (by weight) mortar at ages of 7, 28, 56 and 90 days.

In tests including Ca Cl_2 admixtures, from 1 to 5 per cent. solutions of Ca Cl_2

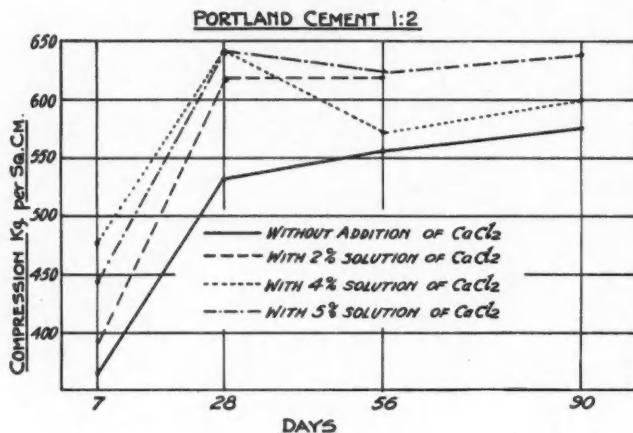


Fig. 1.

were used as mixing water. Dry admixtures of calcium chloride were not used, first, because it was desired to obtain results comparable with Killig's series, second, because the hygroscopic property of calcium chloride is so high that undoubtedly partial setting results during the making of the specimens; the results of such tests being only of an imaginary value. Though in these tests a certain reduction of time of setting was also observed—from 4 hours 25 minutes to 3 hours 15 minutes—there could be no question of a change to quick-setting properties, for no difficulty was encountered in making the specimens in accordance with German standards.

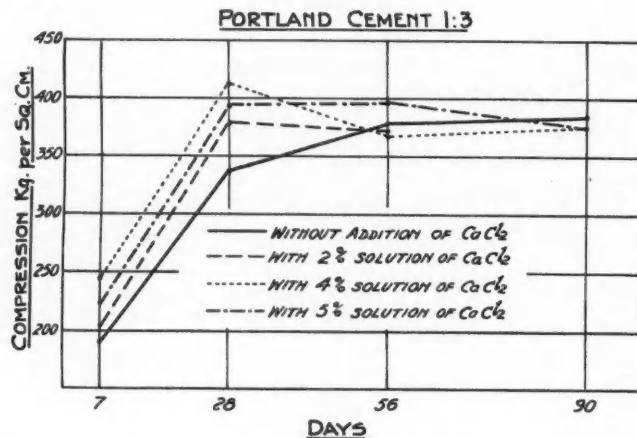


Fig. 2.

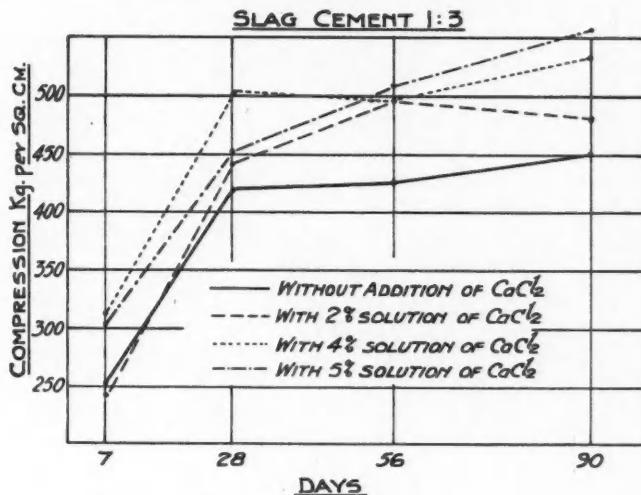


Fig. 3.

The results of these tests are plotted in figs. 1 and 2. They show that a 4 per cent. CaCl_2 solution used as mixing water gives highest increase in compressive strength, while Killig obtained the highest increase with a 2 per cent. solution. In general, the values of tensile strength remain unchanged. At later ages these values show a slight retrogression which, strictly speaking, applies also to com-

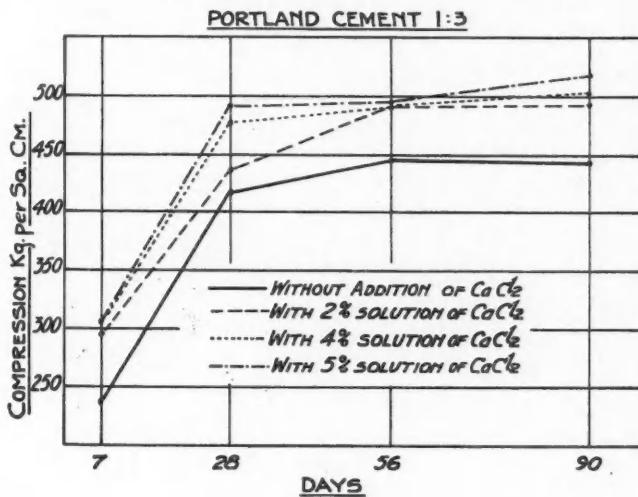


Fig. 4.

pression tests, whose values at 56 and 90' days show less appreciable gain compared with those of specimens without admixture.

Up to this point the effect of calcium chloride appears to depend on two factors. The strongly hygroscopic properties of calcium chloride prevent the formation of hair shrinkage cracks in the specimens by absorbing moisture from the air, and thus keeping the cement through the first period of hardening from too rapid drying. This theory would explain the gain in compressive strength up to the age of 28 days; the subsequent decrease in strength with a correspondingly flattened slope of the curve could be explained by the destructive action of calcium chloride at later ages, when, as soluble chloride, it acts in the same way as sulphates, producing instead of the calcium sulpho-aluminate a similar chloro-aluminate.

The presumably beneficial effect of calcium chloride on cements with gypsum admixtures consists, in my opinion, in an initial retarding of the harmful action of gypsum due to the high solubility and hygroscopic properties of calcium chloride, while at later ages the specimens probably show the destructive action of both gypsum and calcium chloride. This theory is supported by the assumption expressed by Killig, that increased crystalline growth is produced with higher temperature during setting. This assumption appears reasonable, as I have found similar conditions in another connection. It was shown that at ordinary temperature, calcium chloride reacts with cement actively enough to accelerate crystalline growth during setting in the presence of calcium chloride

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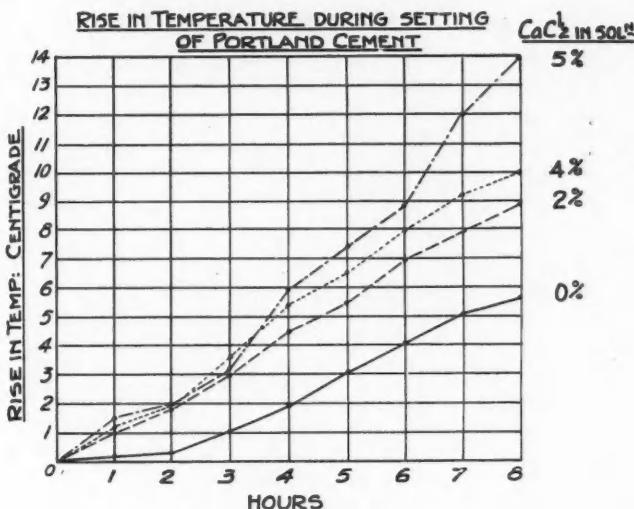


Fig. 5.

with simultaneous formation of tricalcium aluminate ($3 \text{ CaO} \cdot \text{Al}_2\text{O}_3$), and considerable rise in temperature. There can be no doubt that this greater affinity is based on greater solubility of lime in calcium chloride solutions.

It appeared possible to find further ratification of this theory, first by recording the temperature rise during setting, and second by operating with two cements differing greatly in lime content, such as a Portland cement and slag cement (blast-furnace iron slag), which in all physical requirements such as fineness, soundness, and time of setting conformed to German specifications 0, 2, 4 and 5.

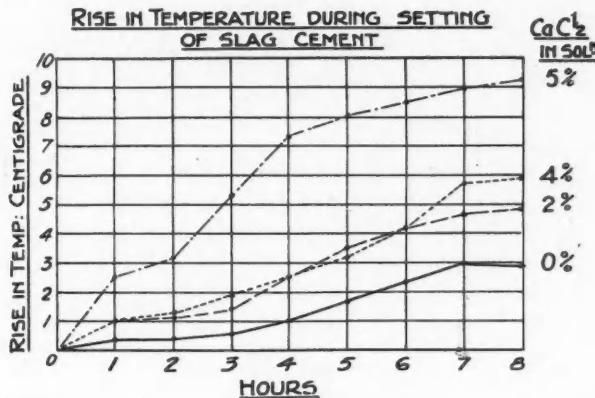


Fig. 6.

per cent. Ca Cl_2 solutions were used as mixing water. The specimens were made of 1:3 mortar. The results are plotted in figs. 3 and 4.

The results of these tests are evidently similar to those quoted above, but they show essential differences in some respects. It is well known that unsoundness first becomes evident in the tensile test results, and that the limit of compression is related to a certain brittleness of the concrete. For the pronounced retrogression of compressive strength and from the apparently higher resistance of slag cement, we may conclude that the effect of calcium chloride depends to some extent on the lime content; but these tests are not extensive enough for one to be definite on this point and a great deal depends also upon the manner in which the specimens are made.

In the tests which were to show the rise in temperature during setting use was made of Killig's thermo apparatus. This is a calorimeter which, though it does not permit a record of absolute temperatures during the setting process, nevertheless gives an idea of the relative values obtained for the two cements, thus making a comparison possible. Each test involved the use of a 1,000-gm. sample of cement with 29 per cent. liquid, which was successively a 0, 2, 4 and 5 per cent. solution of calcium chloride. The data are plotted in figs. 5 and 6. The temperature is given in degrees Centigrade.

The low rise in temperature recorded for the slag cement with a Ca Cl_2 admixture indicates its relation to the lime content of a given cement. It thus offers another proof of Killig's theory. This test also failed to show a radical change in time of setting, although a certain reduction was recorded. To obtain comparable results, care was taken to keep the room temperature constant. The increase in compressive strength recorded for slag cement is naturally a result of the effect of calcium chloride counteracting shrinkage by keeping the specimens moist.

It is quite certain, and has been confirmed, that the use of calcium chloride is, to a certain degree, beneficial to the soundness of cement mortars at early ages. According to Dr. Goslich, Michaelis pointed out a number of years ago that calcium chloride might be a means for correcting unsoundness of under-burnt cement, but at the time he was not aware of the fact that a dry admixture was to be avoided for reasons cited above.

The practical significance of calcium chloride admixtures is limited for the following reasons. First, the possible unfavourable results are not sufficiently clear; second, high early strength cements are now being manufactured, and third, the cost of calcium chloride prevents its extensive application. Recent investigations of the Ca Cl_2 problem by V. Frost have shown that only in the presence of high calcium chloride admixtures does the freezing point of the mixing water become appreciably lowered to be of any practical significance. The use of such a large amount of calcium chloride is, however, not advisable.

The conclusions may show that many a problem is still awaiting its ultimate solution. The present article pretends in no way to give a solution of the Ca Cl_2 problem, and it is possible that further reasons will be found for the peculiar behaviour of cement in the presence of a Ca Cl_2 admixture. However, should these notes provide a stimulus for further research in this domain, its end will be fulfilled.